

APPLICATION FOR
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FOR

MOLECULAR SEPARATOR

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PRIORITY CLAIM

This application claims the benefit of U.S. Provisional Application No. 60/540,492, filed January 30, 2004, the disclosure of which is incorporated herein by reference.

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BACKGROUND OF THE INVENTION

1. Technical Field

The present invention relates to methods and apparatus for the physical separation of solids from fluids, and fluids from gases. More specifically, the invention relates to methods and
10 apparatus for separating solids and dissolved constituents from fluids using an arrangement of separators and concentrators, which are pneumatically pressurized and depressurized at desired intervals via electronically controlled poppet valves, which results in the separation of particulates and dissolved constituents from the untreated fluid media.

15 2. Description of Related Art

The safe and effective removal of contaminants from fluids is a consistent problem faced by many industries. The impurities accumulated by water and other fluids during the hydrologic cycle, and as a result of use by humans, may appear in both suspended and dissolved forms. Suspended solids may be generally classified as particles larger than molecular size (i.e. particle
20 sizes greater than 10^{-3} mm), which are supported by buoyant and viscous forces existing within water. Dissolved materials (i.e. particle sizes less than 10^{-3} mm) consist of molecules and ions, which are held by the molecular structure of water.

The presence of suspended and/or dissolved solids in water, wastewater and other fluids is undesirable for several reasons. The presence of visible suspended solids may be aesthetically
25 displeasing. Likewise, the presence of suspended and/or dissolved solids allows for the adsorption of other chemicals or biological matter into the fluid. Due to the standards promulgated by government agencies, excessive contaminants must be removed from wastewater and other types of contaminated fluid streams before the effluent may be discharged to the

environment or recycled. If established discharge-contamination levels are exceeded, cities and other governmental authorities may impose surcharges and penalties on the entity responsible for the excessive discharge.

There are many industries in which water and other fluids are typically used to clean equipment and other components, such as the aircraft, petroleum and automotive industries. This wash water typically contains significant amounts of suspended solids, dissolved minerals, and organic materials, including oils and other hydrocarbons. Detergents and other chemicals used in the wash operations and drilling operations present further difficulties only increasing the effluent fluid discharge concerns.

The prior art contains multiple attempts to improve the process of separating particles from a fluid. For instance, U.S. Pat. No. 5,647,977 discloses that the water from vehicle wash facilities can be completely recycled, without water discharge. However, where the cost of water is not a factor and the public sewage system can accept certain contaminants, a complete recycling system may not be cost justified. In such systems, aeration by dissolved oxygen can be used to eliminate foul odors without the foaming problems typically caused by continuously bubbling air in the sumps. Additional treatment to remove the suspended solids and reduce the organic materials (other than detergents) in the sump can render the water suitable for reuse, e.g., in the washing part of a vehicle wash cycle, or for discharge where permitted in selected public sewage systems.

A need exists in the art for a portable, highly efficient filtration apparatus and method which can separate suspended and dissolved solids in a variety of environments. Further, a need exists for an improved apparatus and method of removing particles from fluids in either a liquid or gaseous state. Further, a need exists for an apparatus and method which can consistently remove particles of a desired size so as to efficiently and consistently reduce the chance of the imposition of a surcharge for violating quality control standards and releasing untreated effluents.

SUMMARY OF THE INVENTION

The present invention discloses a method and apparatus for separating particles, dissolved matter and chemical sub-fractions from a fluid stream. Specifically, the present invention includes a pneumatic pressure source which transports untreated fluid into a separator. The
5 untreated fluid is placed under pressure sufficient to drive the unfiltered fluid into and through the filter media within the separator. The filtered fluid is then transported to a collection tank. The particulate matter retained on the exterior of the filter media may be removed by the instantaneous reverse pressurization of the separator thereby forcing filtered waste away from contact with the filter media and into a concentrator which can dewater and dry the filtered waste
10 as desired. The concentrated waste is then transported to a waste collection tank where it is retained for appropriate disposal.

The present invention also discloses a novel poppet valve design which insures leak proof function and can be controlled electronically via standard control inputs or pneumatically by the application of positive or negative pressure. The present invention also discloses a novel
15 separator design which utilizes kinetics and cavitation physics to increase filtration efficiency, allowing the separation of chemical sub-fractions from fluid streams below the 1 micron dimension.

BRIEF DESCRIPTION OF THE DRAWINGS

The novel features believed characteristic of the invention are set forth in the appended claims. The invention itself, however, as well as a preferred mode of use, further objectives and advantages thereof, will best be understood by reference to the following detailed description of an illustrative embodiment when read in conjunction with the accompanying drawings, wherein:

Figure 1 is a schematic diagram illustrating the interaction of the functional components of the molecular separator as depicted in accordance with the present invention;

Figure 2 is a schematic diagram illustrating the pneumatic pressure pump in more detail;

Figure 3 is a cross-section view of the filter membrane of the flux cartridge inside the annulus of a separator;

Figure 4 is a schematic view illustrating the pneumatic ejector pump in more detail;

Figure 5A is a rear view pictorial diagram of a preferred embodiment of the molecular separator apparatus;

Figure 5B is a front view pictorial diagram of the molecular separator apparatus;

Figure 6 is an exploded perspective view diagram of a separator filter pod;

Figure 7A is an end on view of the top of the valve heads;

Figure 7B is an end on view of the bottom of the valve heads;

Figure 8A is an end on view of the top of the first transition plate;

Figure 8B is an end on view of the bottom of the first transition plate;

Figure 9A is an end on view of the top of the second transition plate;

Figure 9B is an end on view of the bottom of the second transition plate;

Figure 10A is an end on view of the top of the third transition plate;

Figure 10B is an end on view of the bottom of the third transition plate;

Figure 11A is an end on view of the top of the main body of the separator filter pod;

Figure 11B is an end on view of the bottom of the main body of the separator filter pod;

Figure 12A is an end on view of the top of the fourth transition plate;

Figure 12B is an end on view of the bottom of the fourth transition plate;

Figure 13A is an end on view of the top of the fifth transition plate;

Figure 13B is an end on view of the bottom of the fifth transition plate;

Figure 14 is a cross section schematic diagram of the poppet valves and poppet valve heads;

Figure 15 is a side pictorial view of a flux cartridge;

5 **Figure 16** is a cross section schematic diagram illustrating a concentrator in more detail;

Figures 17-79 are schematic diagrams that depict the process flow of a complete filtration and ejection cycle for two separator filter pods operating in parallel and two concentrators operating in parallel; and,

10 **Figures 80 and 81** are tabular depictions of the valve opening and closing sequences that correspond to the flow diagram sequence depicted in **Figures 17-79**.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT

Referring now to **Figure 1**, a schematic diagram illustrating the interaction of the functional components of the molecular separator is depicted in accordance with the present invention. An untreated fluid containing suspended particles and dissolved matter is placed in a starting or contaminated fluid storage tank **101**. This untreated fluid may include contaminated water, industrial solvents, or any similar fluid or solid from which sub-fractions are to be separated. The present invention can separate liquid from liquid, gases from liquids, and gases from solids. For example, the untreated fluid might be water contaminated with oil, iron, lead or other toxins or waste products. Another example of the fluid to be treated is brine made of zinc bromide (often used to flush drilling holes) from which dissolved solutes are removed such as iron.

The filtration process begins by drawing the untreated fluid from the starting tank **101** by means of a first pneumatic pump **110**. The pneumatic pump **110** alternately draws the untreated fluid through two poppet valves **111**, **112** via the upward and downward motion of the plunger **113**, and alternately pumps the fluid through two out lines **114**, **115**. As the plunger **113** rises (as show in the present example), fluid is drawn through poppet valve **112**. Simultaneously fluid is pumped out through line **114**. When the plunger **113** reverses direction and pushes downward, valve **112** closes and the untreated fluid is drawn through poppet valve **111** and pumped out through line **115**.

The untreated fluid moves through lines **114**, **115** to a separator annulus **120**. For the purposes of **Figure 1**, a single separator annulus **120** with flux cartridge **121** inserted therein is shown for ease of illustration. In a preferred embodiment of the present invention, eight such annuli are contained in a single separator filter pod. Within the center of the annulus **120** is a filter media or flux cartridge **121**. The flux cartridge **121** is the membrane that filters out the desired product from the untreated fluid. A space (referred to herein as fluid ring **122**) exists between the inside surface of the annulus **120** and the outer surface of the flux cartridge **121**. As untreated fluid is pumped through line **114**, it passes through poppet valve **124** on top of the

annulus 120 and into the fluid ring 122. When the untreated fluid is pumped through line 115, poppet valve 124 closes and the fluid passes through poppet valve 123 into the fluid ring 122.

Once in the fluid ring 122, the untreated fluid moves in a turbulent manner (described in more detail below), allowing the desired product (e.g., water, zinc bromide, etc.) to pass through the flux cartridge membrane and into the interior chamber of the flux cartridge 121, leaving behind larger particles and molecules as residue in the fluid ring 122 and the exterior of flux cartridge 121. The pressure supplied by pump 110 pushes the filtered product out of the center of the flux cartridge 121 through a valve 127 and into a second pump, called a pneumatic ejector pump 130. Alternatively, the filtered fluid product may leave the flux cartridge 121 through an ejector bypass valve 128 and travel directly to a product collection tank 102. This ejector bypass is used when a single ejector pump 130 services multiple separator filter pods in alternative embodiments of the present invention.

During the filtration cycle described above, the ejector pump plunger 131 is drawn up (as shown in Figure 1), which opens check valves 132, 133 that are built into the plunger's disc. In this position, the check valves 132, 133 allow the filtered product coming from the flux cartridge 121 to pass by the plunger 131 and out of the ejector 130 and into the product collection tank 102. This filtration cycle repeats for a pre-determined time period (e.g., 20-25 seconds). At the end of this pre-determined cycle period, the separator is backwashed and cleaned with a reverse flush.

The reverse flush operation begins by stopping first pump 110 and shutting the poppet valves 123, 124 at the top of the separator filter pod in which the annulus 120 is contained. Next, the pneumatic ejector 130 is activated and plunger 131 is driven downward. This motion closes the check valves 132, 133 and stops the flow of filtered fluid past the plunger 131, allowing the plunger to exert pressure on the fluid inside the ejector. The fluid is pushed back through valve 127, through the flux cartridge 121 and into the fluid ring 122. The time period for this reverse ejection flush is approximately 0.35 seconds and is carried out under higher pressure than the normal filtration cycle driven by pump 110. For example, the pressure exerted on the untreated fluid by pump 110 may be up to 150 psi (depending on the viscosity of the fluid involved). In

contrast, the pressure exerted by the ejector **130** during the reverse flush may be up to 250 psi. This quick, high-pressure reverse burst removes any particles and residue remaining on the outside surface of the flux cartridge **121** and re-homogenizes the particles and residue in the fluid ring **122** back into solution. Poppet valve **126** on the bottom of the annulus **120** is then opened to
5 allow the pressurized particles and residue solution to flush out of the fluid ring **122** and into a concentrator annulus **140**. The concentrator annulus **140**, as its name suggests, concentrates the waste flushed from the separator annulus **120** by removing a significant portion of the flush fluid used during the reverse flush cycle. Unlike the separator filter pod, which may contain up to eight annuli in the preferred embodiment, the concentrator annulus **140** contains only one
10 annulus with a flux cartridge **141** disposed therein.

The flushed waste enters the concentrator annulus **140** through an open poppet valve **143** and into the interior chamber of the concentrator's flux cartridge **141**. The desired effluent fluid passes through the membrane of the flux cartridge **141** and into the fluid ring **142**, leaving the concentrated waste residue in the interior chamber of the flux cartridge **141**. Poppet valve **147**,
15 which is located at the bottom of the concentrator annulus **140**, allows the filtered fluid in the fluid ring **142** to return to the starting tank **101**. Poppet valve **143**, through which the waste fluid entered the concentrator **140**, is closed and poppet valve **144** is opened to let drying air into the interior chamber of the concentrator flux cartridge **141**. This drying air provides a mechanism to dewater the concentrated waste and drives additional flush fluid through the flux cartridge **141**
20 membrane and through the return poppet valve **147**.

The drying air poppet valve **144** and fluid return poppet valve **147** are then closed, and poppet valve **145**, located on the top of the concentrator **140**, is opened to allow in pressurized purging air. When the air pressure inside the concentrator **140** reaches a pre-determined or desired level (e.g. 110 psi), poppet valve **146** is opened which allows the waste residue inside the
25 flux cartridge **141** to escape into a waste collection tank **103**.

Figure 2 is a schematic diagram illustrating the pneumatic pump in more detail. This view better illustrates the mechanisms by which untreated fluid is pumped into the separator filter pod through alternating channels. The operation of the pump **200** is controlled by

monitoring the position of the top disc **201** as it cycles up and down. A magnetic strip with a positive pole (not shown) is placed inside the circumference of the upper disc **201**. This magnetic strip is detected by two magnetic sensors **210, 211** positioned or attached along the side of the pump **200**. As the upper disc reaches the end point of its movement (up or down), one of the sensors **210, 211** detects its position and relays this to a central controller, which coordinates the function of several solenoids that control the other components in the pump assembly. The sensors **210, 211** are adjustable up and down to facilitate calibration of the pump **200**.

Referring to **Figure 2**, the top disc **201** is moving upward due to pump air entering the lower half of the air chamber **206** through a hose **221**. At the same time, exhaust air is being pushed out of the upper half of the air chamber **205** through another hose **222**.

In the lower portion of the pump **200**, the upward movement of the lower disc **202** draws untreated fluid through a supply line **230** and an open poppet valve **232** and into the lower fluid chamber **204**. Simultaneously, the lower disc **202** pushes fluid from the upper chamber **203** through an upper outflow line **240**. Because the upper poppet valve **231** is closed, fluid is prevented from flowing from the upper chamber **203** back into the supply line **230** during the upstroke. Poppet valves **231, 232** open and closed at the desired intervals able to move fast to control the fluid flow at high pressure. The top disc **201** is approximately six inches in diameter and operated to a maximum pressure of 110 psi at normal water. The lower disc **202** is approximately 5 inches, producing a maximum operating pressure of 150 psi at normal water.

As the upper pump disc **201** reaches the top of its upward movement, its position is detected by the top magnetic sensor **210**. The signal from this sensor **210** is relayed to a central controller, which instructs a control solenoid **220** to reverse the direction of air through hoses **221** and **222**. Therefore, pump air will now move through hose **222** into the upper half of the air chamber **205**, forcing the upper disc **201** downward, and the exhaust air will flow out through hose **221**.

The central controller also instructs a control solenoid (not shown) to open poppet valve **231** and another solenoid (not shown) to close poppet valve **232**. Therefore, as the lower disc **202** moves downward, fluid is drawn into the upper chamber **203** through the upper poppet valve

231. Poppet valve 232, now in the closed position, prevents fluid backflow into the supply line 230 as fluid is pushed out of the lower chamber 204 and through lower outflow line 241. When the upper pump disc 201 reaches the bottom of its movement path, it is detected by lower magnetic sensor 211, which relays the disc's position to the central controller, and the pumping cycle repeats itself as described above.

The pneumatic pump and pneumatic ejector pump may include carbon coated pump rods and piston components, which provides additional corrosion protection from contact with the untreated influent, effluent and waste materials involved in the process. Most of the other components are constructed of stainless steel. The heads of the poppet valves are made of marine brass because of its malleability, which allows the valves to maintain seal integrity over periods of sustained operation.

Figure 3 is a cross-sectional view of the filter membrane 303 of the flux cartridge inside the filter annulus 301. The porous matrix of the filter membrane 303 is created by pressing or sintering metal powder around a bar at high pressure and then annealing it, using well-known metallurgical techniques as is known in the metallurgical art. Other methods of manufacturing filter membranes 303 will be apparent to those of skill in the art. The present invention uses a lower membrane thickness than those found in the prior art (e.g. 1/8 inch versus 3/16 inch), which produces a much higher flow rate through the filter membrane 303. Utilization of these lower thicknesses are possible, in part, due to controlled fluid turbulence which is present in the fluid ring 302 during operation of the invention disclosed herein.

The turbulent flow of the untreated fluid in the fluid ring 302 is represented by curved arrow 310. This turbulent flow is created and controlled by the rhythmic pumping action of the pneumatic pump (pump 101 in Figure 1). As the poppet valves (i.e. 123, 124 in Figure 1) open and close with the alternating fluid streams coming from the pump, a temporary drop in pressure in the fluid ring 302 is caused when the poppets switch position (open or closed), creating a slight suction action after each infusion of fluid. This suction action causes the fluid to pulse up and down within the fluid ring 302, resulting in the turbulence represented by arrow 310. This turbulence is magnified or increased by the speed of the fluid moving through the relatively small

space in the fluid ring.

When fluid flows smoothly without turbulence, the flow is called laminar. Typically, when a fluid is flowing this way it flows in straight lines at a constant velocity. If the fluid hits a smooth surface, a circle of laminar flow results until the flow slows and becomes turbulent. At faster velocities, the inertia of the fluid overcomes fluid frictional forces and turbulent flow results, producing eddies and whorls (vortices).

The present invention utilizes turbulent fluid dynamics to manipulate molecular kinetics such that only the desired, smaller molecules will pass through the membrane matrix **303**, shown by arrow **330**. To pass through the membrane **303**, a molecule in the fluid ring **302** has to enter at almost a 90^0 angle or perpendicular to the surface of the membrane **303** when the molecule contacts the membrane, as represented by arrow **320**. Due to the constant fluid turbulence, only the lighter molecules are able to make this turn fast enough to pass through the membrane **303**. Heavier molecules (e.g., hydrocarbons, iron) cannot turn fast enough to reach the appropriate entry vector or angle when they hit the membrane **303**. As shown in **Figure 3**, when heavier molecules hit the uneven surface of the membrane surface, rather than pass through, they careen off and strike similarly sized molecules, causing them to scatter as well and increasing the kinetic energy present in the fluid ring between the annulus and flux cartridge. This kinetic pattern is illustrated by arrow **340**.

In the absence of fluid turbulence or when laminar fluid flow conditions exist, the heavier molecules in the fluid stream would lose a majority of their kinetic energy and be able to enter the membrane at the appropriate vector. Thus, fluid turbulence is necessary to keep the heavier molecules bouncing off the surface of membrane **303**. As fluid turbulence increases, the smaller a molecule has to be in order to turn and make the appropriate entry vector to pass through the membrane **303**. Therefore, the filtration of smaller molecules can be accomplished by using a flux cartridge with a less porous membrane matrix and/or increasing the fluid turbulence within the separator fluid ring **302**.

The present invention also provides a novel method of achieving the filtration of increasing smaller particle and molecule sizes by membrane emulation, since the filtering effects

of a smaller membrane matrix can be achieved without actually changing the porosity of the flux cartridge interstices. Referring back to **Figure 1**, a slipstream poppet valve **125** controls the flow of fluid from the separator fluid ring **122** to a slipstream fluid hose or path **104** that feeds back to the start tank **101**. During membrane emulation, this slipstream poppet valve **125** is opened while the first pneumatic pump **110** is pumping pressurized untreated fluid into the separator fluid ring **122**, which allows the untreated fluid to move through the fluid ring **122** at a faster velocity due to the increased pressure differential. As explained above, as fluid velocity increases so does fluid turbulence. With the membrane emulation technique, the present invention is able to turn, for example, a five-micron filter into the functional equivalent of a one-micron filter by increasing the turbulent flow of fluid in the separator fluid ring **122** due to the large pressure differential created by the slipstream path **104**.

Returning to **Figure 3**, another chemical effect produced by the filter matrix is cavitation of the filtered fluid as it passes through the membrane **303**. Cavitation (the formation of bubbles) is produced when the static pressure in a fluid falls below the temperature-related vapor pressure. A forceful condensation (implosion) of the bubbles occurs when the fluid reaches a region of higher pressure. In the present invention, as the filtered fluid passes through the membrane **303**, cavitation produces gas bubbles. When these gas bubbles reach the inner space of the flux cartridge (arrow **330**), they rapidly implode. During this implosion process, like molecules come together (flocculation) and form precipitates, which allows targeted separation of dissolved material from the filtered fluid. Yet another chemical effect produced by the filter matrix is the break up of emulsions in the filtered fluid. As the filter fluid is pushed through the membrane **303** under pressure, emulsions in the fluid are broken. By using different size filter matrices and fluid velocities, the present invention is capable of separating particles from 300 microns down to 58 Angstroms.

Figure 4 is a schematic view illustrating the pneumatic ejector pump **400** in more detail. The cycling action of the pneumatic ejector pump **400** is controlled by a solenoid **410** that alternates the pump air between two hoses **411**, **412**. However, unlike the first pneumatic pump, the cycling of the pneumatic ejector pump **400** is not monitored by magnetic sensors. As shown

in **Figure 4**, the upper disc **401** is pushed up by air coming into the bottom half of the air chamber **404** through the lower hose **412**. At the same time, exhaust air is pushed out of the upper air chamber **403** through upper hose **411**. As the lower disc **402** is pulled up, check valves **431**, **432** built into the seal around the disc are pulled open by friction. Once the ejector **400** is in this upper position, the pump air through the solenoid **410** is cut off, and the ejector is held in this position for the duration of the filtration cycle. As filter fluid product leaves the separator filter pod, it enters the pneumatic ejector fluid chamber **405** through line **421**. Because the check valves **431**, **432** are held open in this upstroke position, the fluid product is able to pass by the lower plunger disc **402** and flow out to a collection tank through line **422**.

When the reverse flush cycle is executed, the solenoid **410** directs pump air through the upper hose **411** into the upper half of the air chamber **403**, which drives the upper disc **401** downward, forcing exhaust air out of the lower half of the air chamber **404** through the lower hose **412**. As the lower disc is pushed down, friction from the seal closes the check valves **431**, **432**, preventing fluid from passing through. As a result of the closed check valves **431**, **432** fluid in the chamber **405** is forced back out through line **421** and back into the flux cartridges positioned within the separator as previously shown herein.

During the reverse flush, the time required for the pneumatic ejector **400** to begin exerting pressure is less than approximately 0.10 seconds and the time required to complete the downward stroke is approximately 0.35 seconds. The top disc **401** is approximately six inches in diameter and operated to a maximum pressure of 110 psi at normal water. The lower disc **402** is approximately 4 inches in diameter, producing a maximum operating pressure of 250 psi at normal water. The combination of higher fluid pressure and short stroke time make the reverse flush operation a sudden, shock load to the separator, which aids in the complete and expeditious removal of waste residue from the outer surface of each flux cartridge positioned within the separator annuli.

Figure 5A is a rear view pictorial diagram of a preferred embodiment of the molecular separator apparatus. In this view one can see the separator filter pods **501**, **502** that contain the separator filtration annuli and flux cartridges disposed therein, as well as the concentrators **510**,

511. **Figure 5B** is a front view pictorial diagram of the apparatus, which depicts the pneumatic pumps **520, 521**, various fluid connection lines and a control panel **530**. First pneumatic pump **520** is the positive pressure pump that pumps the untreated fluid into the filter annuli. Pneumatic ejector pump **521** provides the reverse flush fluid and pressure for backwashing the separator pod(s) and transporting the waste residue into the concentrators **510, 511**. The first pneumatic pump **520** and pneumatic ejector pump **521** are positioned vertically to facilitate even surface wear during operations. The control panel **530** includes data entry and control inputs and houses the central controller electronics and circuitry required to operate the invention disclosed herein and allow operator control of the performance of the desired processes disclosed herein. The control panel **530** may also house electronic equipment enabling the remote control of the unit via wired or wireless communication means as is known in the art. The control panel is designed to be capable of being internally pressurized, allowing the invention to be used in hostile environments containing volatile, explosive or corrosive conditions and protecting the enclosed circuitry therein from damage. The storage tanks for the various liquids and products, as well as the connection hoses for the controlling solenoids are not shown in **Figures 5A and 5B** for ease of illustration.

Figure 6 is an exploded, perspective view of one of a separator filter pod. The separator filter pod **600** comprises a main body **605** that contains eight filter annuli disposed therein. At either end of the separator filter pod **600** are valve heads **601, 608** which contain poppet valves which control the inflow and outflow of fluid to and from the separator filter pod **600**. Between the top valve head **601** and the main body **605** are three transition plates **602-604**, which include machined fluid flow pathways for facilitating the distribution of inflow and outflow fluid to and from the separator main body **605**. Two transition plates **606, 607** are placed between the main body **605** and the bottom valve head **608** which include machined fluid flow pathways for facilitating the distribution of fluid flowing into and out of the separator main body **605**. The separator components, including the valve heads, transition plates and main body may be constructed from Hastalloy, 316L stainless steel, or other metal alloys sufficient to provide corrosion protection to the components of the invention and containment of the fluids passing

through same. The preferred embodiment of the present invention uses components fabricated from stainless steel. The separator and concentrator components disclosed herein may be integrated with VITON or CALREZ seals for leak prevention and containment under pressure. VITON seals are preferably used with stainless steel embodiments, while CALREZ seals would be preferable for use with embodiments constructed out of Hastalloy.

Figure 7A is an end on view of the top of the valve heads **601** and **608**. **Figure 7B** is an end on view of the bottom of the valve heads **601**, **608**.

Figure 8A is an end on view of the top of the first transition plate **602**. **Figure 8B** is an end on view of the bottom of the transition plate **602**.

Figure 9A is an end on view of the top of the second transition plate **603**. **Figure 9B** is an end on view of the bottom of the transition plate **603**.

Figure 10A is an end on view of the top of the third transition plate **604**. **Figure 10B** is an end on view of the bottom of the transition plate **604**.

Figure 11A is an end on view of the top of the main body **605**. **Figure 11B** is an end on view of the bottom of the main body **605**.

Figure 12A is an end on view of the top of the fourth transition plate **606**. **Figure 12B** is an end on view of the bottom of the transition plate **606**.

Figure 13A is an end on view of the top of the fifth transition plate **607**. **Figure 13B** is an end on view of the bottom of the transition plate **607**.

The depicted geometric patterns consisting of machined cuts, grooves and holes on and through the transition plates and main body **602-607** are fluid flow channels. These particular geometric patterns are used to ensure even fluid flow to and from the eight annuli in the separator main body **605**. The transition plates may be secured to the main body of the separator and/or concentrator with internal threaded fastening means and external threaded bolt means, which provide easy access and removal of the transition plates for facilitating flux cartridge removal and replacement.

Figure 14 is a cross section schematic diagram of the poppet valve heads **601**, **608**. These poppet valves **1401,1402** are similar to those illustrated in **Figure 2** but are smaller in

dimensional size. The third poppet valve cannot be seen in **Figure 14**, as it is disposed on the opposite side. The poppet valves in **Figure 14** depict the alternating positions of the valves, which allow the flow of fluid flow into and out of the valve heads and to and from the separator and/or concentrator via the transition plates shown in Figures 7A-13B.

5 Relating **Figure 14** to the example in **Figure 1**, when fluid is being pumped through the upper line **114**, valve **124** is open and valve **123** is closed. This can be seen in greater detail in **Figure 14**, with poppet valve **1401** corresponding to valve **124**, and poppet valve **1402** corresponding to valve **123**. When poppet piston **1401** is pulled back into the open position, fluid can enter the separator filter pod through opening **1403**. With poppet piston is extended
10 **1402**, fluid is prevented from entering through opening **1404**. All of the poppet pistons or valves utilized in the invention disclosed herein may also include a circumferential indentation in the head of the piston to retain an O-ring seal **1405** (preferably VITON), as shown in **Figure 14**, to prevent fluid leakage or blowby during operations.

Figure 15 is a side pictorial view of a flux cartridge. In the preferred embodiment, the
15 flux cartridge **1500** is essentially a metallic narrow tube annealed to form a porous media of desired size (e.g. 10 micron, 5 micron, etc.), although other filtration media could be adapted for the desired purpose as is known in the art. The body of the flux cartridge tube **1510** constitutes the filter membrane described herein. Welded to either end of the flux cartridge body **1510** are seating heads **1501**, **1502**, with a circumferential indentation for retaining an O-ring seal
20 (preferably VITON seals) **1503**, **1504**, respectively.

 Flux cartridges are inserted into cylindrical holes that run the length of the separator filter pod main body. The openings of these cylindrical holes are shown in **Figures 6, 11A and 11B**. Each one of the cylindrical holes constitutes a fluid inlet or outlet to an annulus within the separator. The inner portion of the seating heads on the flux cartridges fit into the annulus
25 openings within the separator filter pod main body. The outer portion of the seating heads fit into matching holes in the proximate transition plates **604** and **606**. The matching holes in the transition plates **604**, **606** are shown in **Figures 10B and 12A**, respectively.

Figure 16 is a cross section schematic diagram illustrating a concentrator in more detail.

In contrast to the separator filter pod (which contains eight annuli), the concentrator **1600** contains only one annulus **1610** with a single flux cartridge **1620**. The fluid ring **1630** of the concentrator **1600** is considerably larger than that of the separator filter pod annuli, and the flux cartridge **1620** is also larger than the separator filter pod flux cartridges. This larger size (volume capacity) is necessary since the single annulus **1610** in the concentrator **1600** must process waste fluid from all eight annuli in the separator filter pod.

As described above, a concentrator filters waste fluid in the opposite flow direction in comparison to the separator filter pod. Waste fluid from the separator filter pod flows into the center into the center of the concentrator flux cartridge **1620** as indicated by arrow **1640**. The desired fluid then filters through the membrane of the flux cartridge **1620** into the fluid ring **1630**, similar to the process described above in relation to **Figure 3**. From there, the fluid flows out through the fluid return line back to the start tank, as indicated by arrow **1650**. After waste inflow from the separator filter pod is stopped, drying air enters the center of the flux cartridge **1620** through the same path indicated by arrow **1640**. This drying air pushes additional fluid through the filter membrane of the flux cartridge **1620** and further concentrates the waste.

After the drying air flow is stopped by closing the appropriate valve(s), a burst of purge air enters the fluid ring **1630** as indicated by arrow **1660**. This burst of purge air is similar to the reverse ejection flush used with separator filter pods. Its purpose is to remove waste residue adhering to the flux cartridge **1620**, but in this case, the waste residue must be removed from the inside surface of the flux cartridge **1620** rather than the outer surface which is exposed to the fluid ring **1630**. The purge may also be performed with any other preferred fluid in place of air. The waste removed by the purge is flushed out of the flux cartridge **1620** as indicated by arrow **1670** into a reject collection tank, as previously discussed.

Figures 17-79 are schematic diagrams that depict the process flow at the indicated approximated time interval of a complete filtration and ejection cycle for two separator filter pods operating in parallel and two concentrators operating in parallel. **Figures 17-81** additionally depict the various open or closed positions of the poppet valves, and thus the flow of fluid through the system, during the various states of the operational cycles of the invention

disclosed herein. For the purposes of **Figures 17- 81**, the poppet valves disclosed herein may also be referenced by the indicated numerals (**1701-1726**) as shown in relation to the each referenced valve. For the purposes of the separator filter pods **Q1** and **Q2**, respectively, valves **1701, 1702** and **1707, 1708** may be referred to as the fluid inlet valves, which control the flow of untreated fluid from the start tank to the separator filter pods. Valves **1703** and **1709** are referred to as the ejector bypass valves. Valves **1704** and **1710** are the slipstream valves. Valves **1705** and **1711** are the reject out or contaminant waste valves. Valves **1706** and **1712** are the filtered fluid out valves.

In reference to the concentrators **C1** and **C2**, respectively, valves **1713** and **1718** are referred to as the fluid return valves, which control the flow of return fluid from the concentrators to the initial start tank. Valves **1714** and **1719** are the reject out valves, which control the flow of waste residue from the concentrator to the reject collection tank. Valves **1715** and **1720** are the reject in valves which control the flow of waste fluid from the separator filter pods into the concentrators. Valves **1716** and **1721** control the flow of drying air into the concentrators so as to dry and further dehydrate the waste fluid being concentrated therein. Valves **1717** and **1722** control the flow of air or fluid being introduced into the concentrator for removal of the concentrated contaminants or waste to reject collection tank.

Likewise, and for the purposes of **Figures 17-81**, the pneumatic pump is referenced as **PP** and the ejector pump is referenced as **PEJ**. The valves that control the flow of primary pump air and exhaust to and from the pump and ejector are referenced as valves **1723** and **1724**, respectively. Poppet valves **1725** and **1726** control the flow of untreated fluid from the start tank to the pneumatic pump **PP**. Also depicted are the magnetic sensors **S1, S2**, which monitor the position of the pump piston, as described in detail above.

The process flow depicted in **Figures 17-70** illustrates the use of the ejector bypass, which was briefly described above. The ejector bypass configuration depicted in **Figures 17-19** allows a single ejector to service two separator filter pods. This configuration reduces operating costs compared to using a single ejector for each separator filter pod. For simplicity, only two separator filter pods **Q1, Q2** are depicted in **Figures 17-79**, and as in **Figure 1**, only one annulus

is used to represent each separator filter pod, which would normally contain eight annuli in each pod. This is the same configuration illustrated in **Figures 5A** and **5B**. However, it must be pointed out that a single ejector may service more than two separator filter pods. In the present example, separator filter pods **Q1**, **Q2** are operating in parallel, meaning untreated fluid is being pumped into them directly from the same source.

The approximate time sequence of the valve operation, and the flow sequence during the operational cycle of the present invention is referenced in seconds for each State shown is **Figures 17-81**. For the purposes of disclosure, the states and times shown on **Figures 17-81** are not to be construed as limitations on the function of the invention disclosed herein, but serve as merely an indicator of the approximate time progression throughout the inventive method disclosed herein.

Figure 17 depicts the pre-operational state of the apparatus before operations commence in the referenced operational state.

Figure 18 depicts the commencement of operations wherein untreated fluid is pumped into the separator filter pods **Q1**, **Q2**. Untreated fluid is drawn from the start tank into the fluid chamber of the pneumatic pump **PP** through poppet valve **1726**. Fluid is also pumped from the pneumatic pump **PP** into the fluid rings of separator filter pods **Q1** and **Q2** through poppet valves **1701** and **1702**, respectively. Filtered fluid flows from the first separator filter pod **Q1** through poppet valve **1706** and the ejector **PEJ** and into a product collection tank. Filtered fluid from the second separator filter pod **Q2** passes through the ejector bypass valve **1709** directly into the product collection tank.

Figure 19 depicts the next state in the filtration cycle. The air valve **1723** on the pneumatic pump **PP** changes the direction of the primary pump air and exhaust, causing the pump to reverse direction. Untreated fluid is now drawn into the pneumatic pump **PP** through the second poppet valve **1725**, and is pumped into the separator filter pods **Q1**, **Q2** through the alternate set of fluid inlet valves **1702**, **1708**, respectively. As in **Figure 18**, filtered fluid from separator filter pod **Q1** continues to flow through the ejector **PEJ**, while filtered fluid from pod **Q2** bypasses the ejector **PEJ** and proceeds into the product collection tank.

Figures 20, 22, 24, and 26 depict states identical to Figure 18, and Figures 21, 23, and 25 depict states identical to Figure 19, as the pneumatic pump PP alternates its direction up and down, and demonstrates the repetitive, alternating fluid flow and valve positions during the filtration cycle. The process state depicted in Figure 27 is almost identical to that of Figure 19, with the exception that the flow of untreated fluid to separator filter pod Q1 has been cut off in anticipation of the ejection cycle.

Figure 28 depicts the first state in the ejection cycle for separator filter pod Q1. The air control poppet valve 1724 for the ejector PEJ switches the direction of primary pump air and exhaust, causing the ejector piston to descend and force fluid back through the membrane in the separator filter pod Q1. Poppet valves 1715 and 1713 on concentrator C1 also open in anticipation of waste fluid being flushed from separator filter pod Q1. Since filtered fluid from the second separator filter pod Q2 is moving through ejector bypass valve 1709, it is unaffected by the ejection cycle and continues to receive and filter untreated fluid from the pneumatic pump PP through poppet valve 1708.

The state depicted in Figure 29 is a continuation of the ejection flush of separator filter pod Q1. The pump air valve 1723 again switches the pump air stream, causing the pneumatic pump PP to move downward, drawing untreated fluid from the start tank through poppet valve 1726, and pumping untreated fluid into separator filter pod Q2 through inflow poppet valve 1707. Positive pressure is maintained from the ejector PEJ to separator filter pod Q1. The state depicted in Figure 30 corresponds to the process state depicted in Figure 28, as the filtration cycle for separator filter pod Q2 continues with the pneumatic pump PP switching direction and moving upward, pumping fluid through inlet valve 1708.

As shown in Figure 31, the waste outflow valve 1705 opens, allowing pressurized waste fluid to be flushed out of the separator filter pod Q1 and into concentrator C1 open reject in valve 1715. As fluid flows through the membrane in the concentrator C1, it returns to the start tank through the open fluid return poppet valve 1713.

Figure 32 depicts a reversal of the ejector bypass process as the ejection cycle for separator filter pod Q1 ends. Positive pressure from the ejector PEJ is cut off as poppet valve

1724 switches the direction of primary pump air and exhaust, causing the ejector piston to move upward. Waste outflow valve 1705 on separator filter pod Q1 also closes. As the pneumatic pump PP moves downward, separator filter pod Q1 resumes a new filtration cycle as untreated fluid is pumped into it through open fluid inlet poppet valve 1701. Filtered fluid now flows out of separator filter pod Q1 through the ejector bypass valve 1703 directly to the product tank, rather than through the ejector PEJ. Conversely, filtered fluid leaving separator filter pod Q2 now moves through valve 1712 and the ejector PEJ before reaching the product tank. The concentrator C1, continues to filter fluid from the waste material flushed out of separator filter pod Q1.

As shown in Figure 33, the filtration cycle continues as the pneumatic pump PP moves upward, drawing untreated fluid from the start tank through poppet valve 1725 and pumps it into the separator filter pods Q1, Q2 through inflow valves 1702 and 1708, respectively. Waste inflow valve 1715 on concentrator C1 now closes, as fluid continues to filter through the concentrator membrane.

In Figure 34, drying air flow poppet valve 1716 opens, allowing drying air into the concentrator C1 to dry and dewater the concentrated waste collected within the concentrator. Fluid return valve 1713 remains open to allow filtered waste fluid to return to the start tank via the fluid return line.

In Figure 35 the pneumatic pump PP moves downward, pumping fluid into separator filter pods Q1, Q2 through inflow valves 1701, 1707, respectively.

The states depicted in Figures 36, 38, and 40 correspond to those described in Figure 34. Figures 37, 39 and 41 correspond to the process described in Figure 35, as the alternating filtration cycle continues with the waste residue in the concentrator C1 continuing to dry.

Figure 42 is similar to Figure 34, with the exception that all fluid flow from the pneumatic pump PP to the second separator filter pod Q2 has been cut off in anticipation of the oncoming reverse ejection flush of separator filter pod Q2.

Figure 43 depicts the first state in the ejection cycle for separator filter pod Q2. The air control poppet valve 1724 for the ejector PEJ switches the direction of primary pump air and

exhaust, causing the ejector piston to descend and force fluid back through the flux cartridge membrane in the separator filter pod **Q2**. Poppet valves **1720** and **1718** on concentrator **C2** also open in anticipation of waste fluid being flushed from separator filter pod **Q2**. Since filtered fluid from the separator filter pod **Q1** is moving through ejector bypass valve **1703**, it is
5 unaffected by the ejection cycle and continues to receive and filter untreated fluid from the pneumatic pump **PP** through poppet valve **1702**.

The state depicted in **Figure 44** is a continuation of the ejection flush of separator filter pod **Q2**. The pump air valve **1723** again switches the pump air stream, causing the pneumatic pump **PP** to move downward, drawing untreated fluid from the start tank through poppet valve
10 **1726**, and pumping untreated fluid into separator filter pod **Q1** through inflow poppet valve **1701**. Positive pressure is maintained from the ejector **PEJ** to separator filter pod **Q2**.

The state depicted in **Figure 45** corresponds to that shown in **Figure 43**, as the filtration cycle for separator filter pod **Q1** continues with the pneumatic pump **PP** switching direction and moving upward, pumping untreated fluid through inlet valve **1702**.

15 In **Figure 46**, the waste outflow valve **1711** is opened allowing pressurized waste fluid to be flushed out of the separator filter pod **Q2** and into concentrator **C2**. As fluid flows through the membrane in the concentrator **C2**, it returns to the start tank through the open fluid return poppet valve **1718**.

Figure 47 depicts another reversal of the ejector bypass process as the ejection cycle for
20 separator filter pod **Q2** ends. Positive pressure from the ejector **PEJ** is cut off as poppet valve **1724** switches the direction of primary pump air and exhaust, causing the ejector piston to move upward. Waste outflow valve **1711** on separator filter pod **Q2** also closes. As the pneumatic pump **PP** moves downward, separator filter pod **Q2** resumes a new filtration cycle as untreated fluid is pumped into it through poppet valve **1707**. Filtered fluid now flows out of separator
25 filter pod **Q2** through the ejector bypass valve **1703** directly to the product tank as it did in **Figures 18-31**. Conversely, filtered fluid leaving separator filter pod **Q1** again moves through outflow valve **1706** and the ejector **PEJ**. Both concentrators **C1**, **C2** continue to filter fluid from the waste material with concentrator **C1** still exposed to drying air.

As shown in **Figure 48**, the filtration cycle continues as the pneumatic pump **PP** cycles and pumps fluid into separators **Q1**, **Q2** through inlet valves **1702**, **1708** respectively.

As shown in **Figure 49**, waste inflow valve **1720** on concentrator **C2** closes, as fluid continues to filter through the concentrator **C2** flux cartridge membrane. In **Figure 50**, the pneumatic pump continues to cycle as the filter process continues, and drying air poppet valve **1721** opens exposing the waste contents in concentrator **C2** to drying air. **Figure 51** depicts the continuation of the filtering cycle, as the pneumatic pump **PP** continues to cycle.

Figures 52 and 54 correspond to **Figure 50**, and **Figure 53** corresponds to **Figure 51**, as the filtration cycles continues and the pneumatic pump **PP** cycles up and down providing pressure to drive the untreated fluid to be filtered. The process state in **Figure 55** is similar to that of **Figure 51**, except poppet valve **1716** on concentrator **C1** has closed off the flow of drying air and fluid return valve **1713** has also closed.

In **Figure 56**, the pneumatic pump **PP** continues to cycle and valve **1717** on concentrator **C1** opens, allowing purging air to pressurize the concentrator **C1**. As shown in **Figure 57**, the pneumatic pump **PP** is shown in the downstroke position and reject outflow valve **1714** opens, thereby creating a pressure differential that flushes the waste out of the concentrator **C1** and into a reject collection tank. As the pneumatic pump **PP** cycles and begins an upstroke as shown in **Figure 58**, fluid flow into separator filter pod **Q1** is cut off in anticipation of another ejection flush. Waste outflow valve **1714** on concentrator **C1** is also closed.

Figure 59 depicts the beginning of a second reverse flush of separator filter pod **Q1** as the ejector pump **PEJ** piston cycles downward and forces fluid back through the separator flux cartridge membrane. Poppet valves **1715** and **1713** on concentrator **C1** open again in anticipation of the ejection of waste from separator pod **Q1**.

The sequence of states depicted in **Figures 60-70** is similar to that of **Figures 29-39**, except for the waste material present in concentrator **C2** in **Figures 60-70**. After the second ejection flush of separator filter pod **Q1**, the ejector bypass configuration switches again, and a new filtration cycle begins with **Q1** using ejector bypass valve **1703**, and separator filter pod **Q2** using fluid outflow valve **1712** to the ejector **PEJ**. Waste from the second flush of separator

filter pod **Q1** is filtered and dried in concentrator **C1**, while waste from the first flush of separator filter pod **Q2** continues to dry in concentrator **C2**. As the filtration cycle continues as depicted in **Figure 71**, drying air valve **1721** and fluid return valve **1718** on concentrator **C2** close in anticipation of the purge air cycle. **Figure 72** depicts the purge air valve **1722** on concentrator **C2** opening in preparation for the introduction of purge air into concentrator **C2**.

The state depicted in **Figure 73** is a continuation of **Figure 72**. As the pneumatic pump **PP** cycles, waste in concentrator **C1** continues to dry, while the introduction of purge air into concentrator **C2** pressurizes the waste collected within the concentrator **C2** flux cartridge. In **Figure 74**, the reject outflow valve **1719** on concentrator **C2** opens, creating a pressure differential and allowing the pressurized waste residue to escape into the reject collection tank. Also, poppet valve **1713** is opened, allowing the drying air and any fluid located in the fluid ring of concentrator **C1** to be transported to the start fluid tank for recycling through the system.

In the state depicted in **Figure 75**, the remainder of the waste in concentrator **C2** moves into the reject tank. As the pneumatic pump **PP** continues to cycle and enters an upstroke movement, fluid flow to separator filter pod **Q2** is cut off by the close of poppet valve **1707** in anticipation of a second reverse ejection flush.

In **Figure 76** the ejector **PEJ** pumps fluid back through the membrane of separator filter pod **Q2**. Both the purge air valve **1722** and reject outflow valve **1719** on concentrator **C2** close. As the reverse flush cycle of separator filter pod **Q2** continues in **Figure 77**, waste inflow valve **1720** and fluid return valve **1718** on concentrator **C2** open in anticipation of the waste material to be flushed out of **Q2**. Separator filter pod **Q1** continues its normal filtration cycle as fluid inflow valve **1702** closes and valve **1701** opens. The waste residue in concentrator **C1** continues to dry.

Figure 78 continues the filtration and ejection cycles depicted in **Figure 77**, with separator filter pod **Q2** remaining under positive pressure from the ejector **PEJ** and the pneumatic pump **PP** switching direction as fluid inflow to filter **Q1** switches from valve **1701** to **1702**. As shown in **Figure 79**, the waste outflow valve **1711** on separator filter pod **Q2** opens, allowing the waste material to be flushed into the concentrator **C2**.

The process disclosed herein continues until the desired components are removed or

separated from the untreated fluid tank or as desired by the operator of the system.

Figures 80 and 81 are tabular representations of the poppet valve operational positions during the referenced operational states for the flow process depicted in **Figures 17-79**. A shaded block indicates that the referenced valve is in the open position allowing the flow of fluid there through for the referenced approximated time interval at the referenced state in the process.

The present invention allows multiple separator filter pods and concentrators to be combined in several configurations to improve particular operating characteristics of the system and reduce costs. The separator filter pods provided by the present invention may be operated in parallel (as described above) or in series. Parallel filtration maximizes the volume of fluid that can be treated within a given time frame. However, when separator filter pods are operated in series (meaning filtered fluid flows from one pod directly into the next), they can progressively filter or separate particles and molecule of progressively smaller dimensions. For example, if four separator filter pods are operated in series, the first separator pod might filter particles 20 microns or greater in dimension, the second separator pod at 10 microns, the third separator pod at five microns, and the fourth separator pod at one micron. The size of the particles to be filtered in the above example is arbitrary , but is meant to merely illustrate how multiple separator pods can be configured in series to increase filter and separation efficiency.

Similarly, concentrators may also be used in parallel or series. Similar to the separator filter pods, parallel operation of multiple concentrators maximizes the volume of waste residue that is processed in a given time frame. Operating concentrators in series progressively decreases the fluid remaining in the waste product as the residue move from one concentrator directly into the next concentrator in the formation. The example apparatus shown in **Figure 5A** includes two concentrators **510, 511**. If these concentrators were operated in series, the resulting reject waste is significantly drier than if the concentrators operate in parallel. In a preferred embodiment of the present invention, if a third concentrator is added in the series, the reject waste product which would be discharged after the completion of the process would comprise dry dust. In this form, many considerable advantages of dry waste disposal would be evident, including the decreased volume of space required to dispose of dry dust versus wet sludge.

The present invention can be applied to many industries. Examples include the petroleum industry for separation of waste streams, the aircraft industry for clear water rinses for corrosion control on aircraft, and the pharmaceutical industry. Likewise, the present invention has myriad applications in the polymerization industry, municipal water and waste water treatment, 5 desalinization, catalyst recovery and steel manufacturing. Whereas prior art filter applications lose roughly 30-40% of their efficiency after initial contact with a waste stream, the present invention maintains its effectiveness over extended periods of continual use. For example, a single apparatus of the present invention can process 22,000 gallons of crude oil in 20 hours, bringing it to pipeline grade in one day. Similarly, the inventive apparatus and method disclosed 10 herein can process and convert up to 60,000 gallons of non-potable water into potable water in one day.

Most prior art methods can only process up to 5000 ppm of solids in an incoming influent. In contrast, the present invention can process up to 140,000 ppm solids in the incoming influent. It will be recognized that filtration and treatment rates will vary according to the 15 porosity of the filter media, size and concentration of contaminate fluid to be filtered, and other variable affecting the treatment process. As such, any reference to operating pressures or treatment capacity, timing and the like are presented as approximate values, and are not to be construed as limitations on the inventive disclosure set forth herein.

Depending on the embodiment utilized, the power requirement to power the apparatus 20 and method discussed herein is generally 120 Volts-7 Amperes. The invention is lightweight, weighing approximately 2000 pounds in the preferred embodiment, is highly mobile and maybe stationed on a skid, pallet or wheeled trailer for easy transport to the site. The flow lines and hoses which provide fluid communication pathways between the components of the inventive apparatus disclosed herein may be manufactured as machined stainless steel piping, Hatalloy or 25 from other materials as appropriate for handling the fluids to be treated as well as the operational environment. They may be fitted to the various components of the disclosed invention using threaded connectors, quick connect/disconnect fittings, or by other attachment means as is known in the art.

The description of the present invention has been presented for purposes of illustration and description, and is not intended to be exhaustive or limited to the invention in the form disclosed. Many modifications and variations will be apparent to those of ordinary skill in the art. The embodiment disclosed was chosen and described in order to best explain the principles
5 of the invention, the practical application, and to enable others of ordinary skill in the art to understand the invention for various embodiments with various modifications as are suited to the particular use contemplated.